FINAL REPORT
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Solubility of noble gases and nitrogen in silicate melts to 5000 bars
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A principal source of the atmospheres of the terrestrial planets is volcanism. Volatile constituents dissolve in magmas when they form by partial melting deep in planetary interiors. As the magmas rise toward the surface and the pressure on them decreases, dissolved gases exsolve into bubbles and may ultimately escape into the atmosphere. Although major changes in atmospheric chemistry occur subsequent to degassing by processes such as weathering, interaction with sediments, interaction with ice and water, and loss to space, it is generally accepted that understanding of atmospheric evolution must begin with the volcanic input.

The goals of this project were (1) to measure the pressure and temperature dependence of the solubility of rare gases and nitrogen in a range of silicate melt compositions relevant to planetary volcanism; (2) to study the influence of the major volatile species, water and carbon dioxide, and other rare gases on the solubility of individual rare gases; (3) to measure the diffusivities of rare gases and nitrogen as functions of pressure and temperature in silicate melts; and (4) to develop an understanding of the thermodynamics and, if possible, the solubility mechanisms of these volatile species in silicate melts so as to generalize our results to a wider range of compositions and conditions. The results of this type of work are essential underpinnings to our understanding of the behavior of volatile components during igneous processes on Mars and their possible influence on the composition of the martian atmosphere.

Results of this project can be summarized as follows:

The solubilities and diffusivities of Ar, Kr, Xe, and $N_2$ in a range of silicate glass and melts were measured over a wide range of pressures and temperatures. Many of the measurements utilized the NASA funded synchrotron facility at Brookhaven National Laboratory. The compositions studied span the range of common igneous rock compositions found on earth and anticipated on the other terrestrial planets. The diffusion of water in silicate melts and glasses was also examined and we were able to demonstrate that water diffuses as molecular water, the behavior of which can be directly compared to that of the rare gases. The results of these studies provide a basis for understanding equilibrium (i.e., based on the contrasting solubilities of volatile species in melts) and kinetic (i.e., based on the contrasting diffusivities of volatile species in melts) fractionations among the noble gases and nitrogen that could occur on magmatic degassing.

Details of the results of the completed work of this project can be found in the following publications, all of which were fully or partially funded by this NASA grant:

Journal Articles

Carroll, M.R., E. Paris, and I Davioli (1990) XANES and EXAFS study of Ar and Xe bearing $SiO_2$ glasses. Proceedings 2nd European International Conference on Progress in X-ray Synchrotron Radiation Research (in press).

Carroll, M.R. (1990) Simultaneous determination of inert gas solubility and diffusivity in glasses at elevated pressures and temperatures. J. Non-Cryst. Solids (in press).

Carroll, M.R. and E.M. Stolper (1990) Argon solubility and diffusion in $SiO_2$ glass: implications for the behavior of molecular gas species. Geochim. Cosmochim. Acta (in press).

Zhang, Y., E.M. Stolper, and G.J. Wasserburg (1990) Diffusion of water in rhyolitic glasses. Geochim. Cosmochim. Acta (in press).

Zhang, Y., E.M. Stolper, and G.J. Wasserburg (1990) Diffusion of a multi-species component and its role in the diffusion of water and oxygen in silicates. Earth Planet. Sci. Lett. (in press).

Carroll, M.R. (1990) Diffusion of Ar in rhyolite, albite, and orthoclase composition glasses. Earth Planet. Sci. Lett. (submitted).

Abstracts

Carroll, M.R. and E.M. Stolper (1987) Argon solubility and diffusion in silica glass. Geol. Soc. Amer. Ann. Meeting Abstr., 19, 612.

Carroll, M.R. and E.M. Stolper (1988) Argon solubility and diffusion in rhyolitic and albitic glasses. EOS, 69, 1465.

Carroll, M.R. and E.M. Stolper (1989) Diffusion and solubility of molecular gas species in melts and glasses. Terra Abstracts (EUG V), 1, 271.

Carroll, M.R. (1989) The effect of He on the solubility of Ar in silicate solids and liquids. EOS, 70, 1402.

Zhang, Y., E.M. Stolper, and G.J. Wasserburg (1989) The mechanism of water diffusion in silicate melts. EOS, 70, 501.

Carroll, M.R., E. Paris, and I Davioli (1990) XANES and EXAFS study of noble gases in vitreous silica. Abstracts of 2nd European International Conference on Progress in X-ray Synchrotron Radiation Research (in press).

Carroll, M.R. (1990) Ar diffusion in feldspar and rhyolite composition glasses. Proc. Third International Symposium on Experimental Mineralogy, Petrology, and Geochemistry. Terra Abstracts, 2, 68.

Carroll, M.R., S.R. Sutton, D. Woolum, K. Lewotsky, and P.S.Z. Rogers (1990) Kr and Xe diffusion and solubility in melts and glasses. Lunar and Planetary Science XX, 170-171.

Van der Laan, S.R., A. Kennedy, G.J. Wasserburg, P.J. Wyllie, and Y. Zhang (1990) Preliminary comparison of chemical and self diffusion for K and Ca in andesite and rhyolite melt. EOS, 71, 652.

Zhang, Y., E.M. Stolper, and P.D. Ihinger (1990) Reaction kinetics of $H_2O+O=2OH$, and its equilibrium revisited. V.M. Goldschmidt Conference Abstracts 1990, 94.

Zhang, Y., E.M. Stolper, and G.J. Wasserburg (1990) Role of water during hydrothermal oxygen diffusion in minerals. EOS, 71, 650.

Zhang, Y. (1990) An approximate treatment of uphill diffusion. EOS (in press)